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THE EFFECT OF ORGANIC SEDIMENT CONTENT ON CORAL DIVERSITY IN KARIMUNJAWA ISLAND, INDONESIA

PENGARUH KANDUNGAN ORGANIK SEDIMEN TERHADAP KEANEKARAGAMAN KARANG DI KEPULAUAN KARIMUNJAWA, INDONESIA

Fajar Nugroho[1,2,*], Neviaty P. Zamani[1], and Hawis Madduppa[1]
[1]Department of Marine Science and Technology, Bogor Agriculture University, Bogor
[2] Marine and Fisheries Training Center, Ministry of Marine Affairs and Fisheries, Subang
*E-mail: fajarfathi2010@gmail.com

ABSTRACT

Coral reef now are under threats due to sedimentation. Fatal effect of organic rich sediment, leading corals mortality. Therefore, the study was conducted to investigate effect of organic sediment content to the coral diversity in Karimunjawa Island, Central Java, Indonesia. Field data was conducted at 6 locations. Three sediment traps were deployed at each sites to measure organic sediment content. Twenty replicated quadrant transects were used to estimate coral density and coral diversity. Analysis of variance (ANOVA) was used to examine the differences of organic sediment content in each station. The linear regression was used to assess the relationship between organic sediment content and coral diversity. Our field result demonstrated that sediment content significantly different between sites with value range from 0.42 mg/800 mL - 1.32 mg/800 mL. Based on the Simson's Diversity Index, the highest coral diversity found at Alang-alang as site with low sedimentation while the lowest coral diversity was found at Legon Lele as site with high sedimentation. The study shown significant negative correlation between organic sediment content and coral diversity with the coefficient of regression 0.68. This study convinces that disturbance on coral reefs might affect coral diversity in Karimunjawa Island, in addition to other factors such as the influence of human activities, natural disruption and climate change.

Keywords: sedimentation, organic, coral, diversity, Karimunjawa

ABSTRAK

Sedimentasi saat ini menjadi ancaman bagi terumbu karang. Kandungan organik sedimen, mempercepat degradasi jaringan pada karang. Penelitian ini dilakukan untuk mengkaji pengaruh kandungan organik sedimen terhadap keanekaragaman karang di Kepulauan Karimunjawa, Jawa Tengah. Pengambilan data dilakukan pada 6 stasiun pengambilan data. Sedimen diambil melalui pemasangan sedimen trap sebanyak 3 buah pada masing-masing stasiun. Kepadatan genus karang diestimasi menggunakan transek kuadrat dengan pengulangan sebanyak 20 kali pada masing-masing stasiun. Analisis ragam (ANOVA) dilakukan untuk mengetahui berbedaan nilai kandungan organik sedimen pada setiap stasiun. Selanjutnya dilakukan regresi linier untuk mengetahui hubungan antara keanekaragaman karang dan kandungan organik sedimen. Hasil penelitian menunjukkan bahwa kandungan organik pada sedimen berbeda signifikan antar lokasi pengambilan data dengan rentang nilai 0,42 mg/800 mL – 1,32 mg/800 mL. Indeks Keanekaragaman Simson untuk karang tertinggi berada di stasiun Alang-alang dimana lokasi tersebut mempunyai tingkat sedimentasi yang relatif rendah, sedangkan keanekaragaman terendah berada di stasiun Legon Lele dengan sedimentasi tinggi. Hasil uji regresi statistik disimpulkan bahwa kandungan organik pada sedimen secara signifikan berkorelasi negatif dengan keanekaragaman karang dengan nilai koefisien korelasinya sebesar 0,68. Studi ini membuktikan bahwa gangguan pada terumbu karang oleh kandungan organik sedimen mempengaruhi keanekaragaman karang di Kepulauan Karimunjawa, selain faktor lain seperti pengaruh aktifitas manusia, gangguan alam dan perubahan iklim.

Kata kunci: *sedimentasi, kandungan organik, keanekaragaman, terumbu karang, Karimunjawa*

I. INTRODUCTION

Increasing the sediment contents into coastal ecosystem are considered to be a major cause of degradation of some coastal coral reefs (Devlin and Brodie, 2005). The effects of high sedimentation to hard corals are responded by some deficiencies, such as reduced photosynthetic efficiency generating in bleaching and necrosis (Philipp and Fabricius, 2003), and unaltered vertical extension but low skeletal density in massive corals and increased bio-erosion (Holmes *et al.,* 2000). High sedimentation content caused bio-erosion by increasing abundance of macro boring organism on corals (Macdonald and Perry, 2003) and clean off zooxanthellae (Philipp and Fabricius, 2003). Bryant *et al.* (1998) recognized sediment loading as a significant factor in allocating reefs to high and medium risk categories.

Sediments contain varying proportions of organic particles (Ayukai and Wolanski, 1997). Earlier studies showed that the effect of fine sediments rich in organic matter is more harmful to reduce corals cover, compared to sediments poor in organic matter (Weber *et al.,* 2012). Organic and nutrient-related sediments are key factor in determining sedimentation stress in corals after short-time exposure (Weber *et al.,* 2006). This corresponds to an increased microbial activity on the surface of corals that exposed by organic sediments (Weber *et al.,* 2006; Weber *et al.,* 2012). Increased organic matter in sediments led to increased grow rates of the microbes in the coral's mucus layer leading to coral mortality (Kline *et al.,* 2006). These findings suggested that microbial activity by organic content could be fatal for corals covered with organic rich sediments, subsequently reduces diversity of coral.

Coral reefs ecosystem in Karimunjawa islands has been suffered high damage by anthropogenic activities (Yusuf, 2013). Coral reefs coverage varies between 25%-49% (or medium coverage) and only small part with good condition (50%–74.9 %) coral coverage (Yusuf, 2013). Sedimentation has been found in northern, eastern and western Karimunjawa area (Helfinalis, 1999; 2005). Previous study of sedimentation focused only on total amount of sediment, but ignoring sediment organic particles (Peters and Pilson, 1985; Sofonia and Anthony, 2008). Understanding the effect of organic sediment content on coral reefs diversity is needed to better insight into potential threats of coral reef ecosystem from sedimentation exposure of organic matter. Therefore, this study aims to investigate sedimentation condition by assessing organic sediment content, and to assess the effect of organic sediment content to coral diversity in coastal area of Karimunjawa Islands, Central Java, Indonesia.

II. METHODS

2.1. Study Sites

This study has been conducted in coastal waters of Karimunjawa Islands National Park, Central Java, Indonesia. Field samplings were carried out at 6 sites. Each site is assumed to be different sedimentation condition. Site names are Seruni, Sambangan, Cendikian, Mrican, Alang-alang and Legon Lele (Figure 1). Field sampling were conducted from 18 August to September 2016. Study sites were selected to be similar in depth (6-8 m) and distance from the shore (50-100 m). Data were collected using SCUBA diving.

2.2. Sediment Samples

Three sediment traps were set up at each site for 30 days measurement between August and September 2016. The traps consisted of a PVC tube of 40 cm in length and 5 cm of diameter (volume 800 mL), which is considered optimal for preventing sediment resuspension and measuring gross sediment input (Gardner, 1980). Following sediment trap collection, each PVC tube was gradually poured, and the sediment rinsed with distilled water to remove salts.

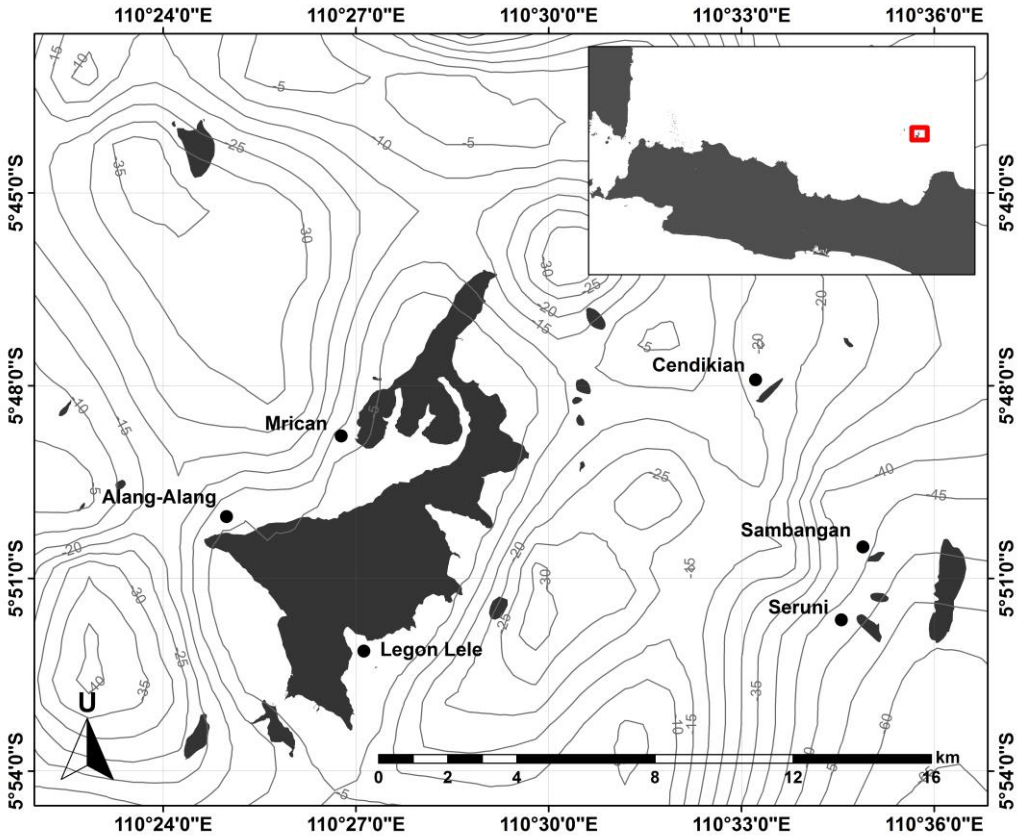

Figure 1. Field sampling stations for organic sediment contents and coral reef survey in coastal area of Karimunjawa Island, Central Java, Indonesia from 18 August to 16 September 2016.

Sediment was filtered with a pre-weighed Whatman GF/C glass microfiber filter in a vacuum pump. The filters were dried at 60°C until constant weight was achieved, weighed, ignited in a furnace at 450°C for 4 hours to remove organic matter, and finally re-weighed for inorganic sediments (Bastidas *et al.*, 1999).

2.3. Coral Reef Diversity

Coral were sampled using 20 replicated quadratic transects (1x1 m) on each site. Each individual hard coral colony with a maximum diameter greater than 3 cm was identified by genus and counted. Coral diversity was calculated using the Simpson's Diversity Index (D'). A diversity index estimated by $D' = 1 - D$, where $D = \Sigma (n/N)^2$, n is the total number of particular genera, N is the total number of organisms of all genera (Hunter and Gaston, 1988).

2.4. Statistical Analysis

Two-way ANOVA were used to examine the differences in organic sediment content. The linier regression was used to assess the relationship between organic sediment content as independent and coral diversity as dependent variable. The program R-Studio 3.3.2 was used for all statistical analysis (Kabacoff, 2011). Linier regression scatterplots were constructed using ggplot2 package in R-Studio 3.3.2 computer program (Kabacoff, 2011).

III. RESULTS AND DISCUSSION

3.1. Organic Sediment Content

Present study showed that organic sediment content at 6 sampling sites ranges between 0.42 and 1.32 mg/800 mL (Table 1). Legon Lele was the site with the highest organic sediment content, whereas the lowest

located at Seruni. Organic content showed significantly different between sites according this study (ANOVA, $p = 0.006$). Seruni, Sambangan and Cendikian are small islands while Mrican, Alang-alang, Legon Lele are sites located around Karimunjawa Island. Legon Lele is located in the estuary on the east of Karimunjawa Island, Mrican and Alang-alang located on the west of Karimunjawa Island. This result is likely due to Legon Lele located in the estuary, whereas Seruni is a small island and located relatively far away from estuary. The sediments found on mainland coast, partly dominated by sediments from the terrestrial runoff that transported by river and rainwater (Helfinalis, 1999).

Table 1. The mean and standard deviation of organic sediment content (mean ± SE) at 6 sampling sites.

Site	Organic Sediment Content (mg/800 ml) ± SE	N*
Seruni	0.42 ± 0.08	3
Sambangan	0.91 ± 0.02	3
Cendikian	0.49 ± 0.08	3
Mrican	0.69 ± 0.07	3
Alang-alang	0.52 ± 0.13	3
Legon Lele	1.32 ± 0.27	3

*N is the number of sediment trap collected at each site.

Terrestrial runoff increases siltation and nutrient availability on coastal area (Weber *et al.*, 2006). Turbid freshwater flowing from the land that is transported by river can discharge high number of fine suspended solids rich in organic (Devlin *et al.*, 2001). Small islands are physically separated to mainland and mostly influenced by marine hydroclimate factor (Fandely and Muhammad, 2009). In contrast to mainland, the substrate and coastal sediments of small islands typically depend on the type of biota around the island, and are usually dominated by coral reefs or rock types present on the islands (Fandely and Muhammad, 2009). Karimunjawa Islands consists of 25 islands with the largest island is the mainland of Karimunjawa (BTN Karimunjawa, 2012). Of the whole island, only Karimunjawa island has a small river (BTN Karimunjawa, 2012), therefore highest sedimentation occur on around the mainland of Karimunjawa island.

3.2. Coral Diversity and Its Relationship Between Organic Sediment Content

A total of 22 hard coral genera were found in all sites during this study (Table 2). The genera found at 6 sites were *Acropora, Montipora* and *Porites.* This study showed that high number of *Porites* was found at sites with high organic sediment content (i.e., at Legon Lele). *Porites* is associated with opportunistic live histories believed to enhance persistence in frequently disturbed environment (Szmant, 1986; Soong, 1991). Study by Torres and Morelock (2002) showed that coverage and linear extension rate of *Porites astreoides* were not affected by decreased significantly in reef with a high content of sediment. *Montipora* is genera was found in 6 sites. This is assumed that *Montipora* resists in various sedimentation condition. This result is in good agreement with Hodgson (1990), showing that *Montipora* was not injured and may be physiologically resistant to sedimentation damage.

Based on Simpson's Diversity Index (D'), the highest coral diversity found at sampling site Alang-alang, while the lowest coral diversity was at Legon Lele (Table 3). The highest genera richness was found at Alang-alang and Seruni (15 genera), while the lowest was documented at Mrican (7 genera). Mrican recorded as site with low organic sediment content, but the genera richness is the lowest and coral density relatively lower than other sites. This fact was contrast with previous study, showing that organic sediment content has inverse relationship with the species richness and

coral density (Lirman *et al.*, 2003; Weber *et al.*, 2012). This is likely associated with the field sampling time. Data were collected during the Southeast Monsoon period (August – September 2016), when the southeasterly winds are fully developed in Java Sea as well as in Karimunjawa. Consequently, at Mrican sampling site that located on the western part, sea state was relatively calmer because it is protected from the southeasterly winds. Because of calmer waters, low sediments were caught by sediment traps, but depth sediments (5-10 cm) were found settle at the bottom. Sediment depth is an important factor determining the location and extent of habitat suitable for coral settlement and survivorship (Lirman *et al.*, 2003). Wherever mean sediment depth exceeds 10–15 cm, sea-grasses are the dominant benthic organisms (Lirman and Cropper, 2002) and only isolated colonies of the coral *Porites spp.* are found among the seagrasses (Lirman *et al.*, 2003). During this study, *Porites* was found with the highest number at Mrican sampling site.

The coral diversity was significantly negative correlated with the organic sediment content. High coral diversity were found at sites with low organic sediment content, i.e. at Alang-alang and Seruni sampling sites. Conversely, low coral diversities were found at sites with high organic content, for example at Legon Lele. Linier regression between Simpson's Diversity Index and organic sediment content is presented in Figure 3.

Table 2. Coral density (colony/20 m^2) at each sites.

No	Genus/sites	Seruni	Sambangan	Cendikian	Mrican	Alang-alang	Legon Lele
1	*Acropora*	45	92	37	2	20	5
2	*Alveopora*	-	2	-	-	-	-
3	*Diploastrea*	-	-	-	-	1	-
4	*Echinopora*	1	-	-	-	-	1
5	*Favia*	3	8	-	-	-	1
6	*Favites*	4	7	-	21	8	7
7	*Fungia*	9	170	3	-	25	1
8	*Galaxea*	-	117	3	-	13	-
9	*Herpolitha*	2	-	-	-	-	-
10	*Leptoseris*	1	-	-	-	-	-
11	*Merulina*	1	-	-	3	2	1
12	*Millepora*	12	-	-	-	1	1
13	*Montipora*	19	97	80	8	31	5
14	*Oxypora*	-	-	-	-	1	-
15	*Pachyseris*	8	3	6	-	10	1
16	*Pavona*	1	-	1	-	4	1
17	*Plerogyra*	-	-	-	-	3	-
18	*Pocillopora*	7	7	2	1	-	1
19	*Porites*	38	59	18	46	46	50
20	*Psammocora*	1	-	-	1	-	-
21	*Stylophora*	-	2	-	-	1	-
22	*Symphyllia*	-	3	-	-	4	-

Table 3. Simpson's Diversity Index (D') in overall sites.

Sites	Seruni	Sambangan	Cendikian	Mrican	Alang -alang	Legon Lele
Simpson's Diversity Index (D')	0.81	0.71	0.75	0.60	0.84	0.54

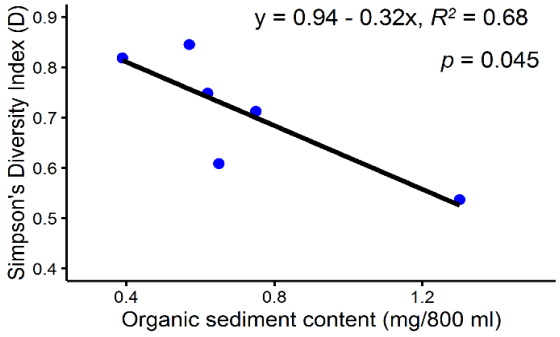

Figure 3. The linear regression between Simson's Diversity Index and organic sediment content at 6 sampling sites.

This means that increase of organic sediment content reduces the coral diversity. It is associated with fatal effect of organic rich sediment to the corals by increased growth rates of the microbes in the coral's mucus layer, leading to coral mortality (Kline *et al*., 2006). Weber *et al*. (2012) found that sedimentation kills corals through microbial processes triggered by the organic matter in the sediments, namely respiration and presumably fermentation and desulfurization of products from tissue degradation. Increased microbial activity reduced O_2 and pH initiating tissue degradation, then the hydrogen sulfide formed by bacterial decomposition of coral tissue and mucus diffuses to the neighboring tissues, accelerating the spread of colony mortality (Weber *et al*., 2012). Their data suggest that the organic enrichment of coastal sediments is a key process in the degradation of coral reefs exposed to terrestrial runoff (Weber *et al.*, 2012). Nutrient enrichment by organic sediment content may also increase algal abundance on reefs (Littler *et al.*, 2009). Coral-algal competition reduces coral recruitment, growth and survivorship (Birrel *et al.*, 2008). Zaneveld *et al.* (2016) found evidence that algal contact induces coral microbiome instability resulting tissue loss and mortality.

IV. CONCLUSION

In conclusion, our study demonstrated that organic sediment content in Karimunjawa Islands varied significantly according sites condition. High content of organic matter on sediment significantly lessens diversity of coral.

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